

**METHOD AND APPARATUS FOR RANGE EXTENSION OF LOW-POWER
WIRELESS COMMUNICATION LINKS**

Background of the Invention

Field of the Invention

The present invention relates to wireless devices, and more particularly to methods for improving transmission services between such devices.

Description of the Related Art

[1001] As the number and type of electronic devices have proliferated, so have the number and type of connectors and protocols for communicating between the electronic devices. For example, televisions, personal computers (and associated peripheral devices), personal digital assistants (PDAs) and mobile telephones all typically require different methods for communicating with other electronic devices. As a result, a given electronic device must either embrace multiple communication techniques (e.g., a personal computer may support different protocols for different peripheral devices, and may have one or more serial, parallel and infrared I/O ports), or do without the ability to communicate with a particular device. Moreover, even if an electronic device has the ability to support a plurality of communication techniques, the corresponding increase in associated processing power and the number of cables/connectors to provide such support can prove cumbersome or prohibitive.

[1002] The Bluetooth standard protocol was developed with the above in mind, and provides a single protocol for wireless communications between a plurality of different types of electronic devices. As such, this protocol overcomes many or all of the problems described above. Bluetooth is described in more detail in, for example, *Specification of the Bluetooth System*, v0.8, January 22, 1999 (and in subsequent revisions thereof), which is hereby incorporated herein by reference and may hereinafter be referred to as the "Bluetooth specification."

[1003] In addition to overcoming the above-discussed problems, Bluetooth also permits the grouping of physically proximate wireless devices into local networks known as "piconets."

110). However, the present invention allows device 110 to continue to transmit to device 120 over an increased effective transmission range 140.

[1022] Fig. 2 demonstrates a block diagram of wireless communications device 110 just discussed. In Fig. 2, device 110 includes a transmitter 210 and receiver 220, which transmit and receive data via antenna 230. Operating in conjunction with transmitter 210 and receiver 220 is error-correcting coding mechanism 240, which is operable to increase a level of error-correcting coding applied to data sent by transmitter 210, such that transmission range 130 in Fig. 1 is effectively increased to transmission range 140. The theory underlying the operation of error-correcting coding mechanism 240 is discussed in more detail below.

[1023] Bluetooth is a standard for digital transmission, and, as with most digital transmissions, it relies on error-correcting coding to transmit and receive signals at a certain speed and level of reliability. Error-correcting coding (ECC) essentially deals with the situation where a “1” is mistaken for a “0” (or vice-versa) in a digital transmission. Such errors can occur, due to, for example, electronic noise, component defect, etc. ECC uses various coding techniques to identify and correct these errors.

[1024] ECC relies on the inclusion of redundant information (bits) in a signal, which contains information about the data that can be used to correct the above-mentioned difficulties. In general, the more ECC bits that are included with the data in a given transmission, the more errors can be tolerated in that transmission. However, ECC requires processing beyond what would otherwise be required; therefore, a message transmitted using ECC will either require more processing power and/or additional transmission time.

[1025] As a given signal transmits over a certain distance, its bit error rate also increases. Hence, based on the above, the present invention seeks to increase an effective transmission range of a device by increasing a level of error-correcting coding applied to a signal that is transmitted by that device. In other words, since the effect of increased distance is a lower signal-to-noise ratio that manifests as an increased bit error rate, additional coding allows the same signal to be correctly decoded at a greater range.

[1026] Bluetooth typically utilizes an access code at the start of each message burst. Such an access code can serve multiple purposes. For example, a channel access code usually provides identification of devices in a piconet, including which member is the master (which could be either the device itself, or the destination device if the transmitting device is a slave). A device

access code may identify special procedures or functions of a device; e.g., paging, etc. An inquiry access code is generally used to determine which (if any) additional Bluetooth devices are in range.

[1027] Inquiry access codes can generally be divided into two types: general and dedicated. General inquiry access codes are used to determine whether any Bluetooth device is within transmission range. Dedicated inquiry access codes (DIACs) are used to determine whether any Bluetooth device sharing a common characteristic is within transmission range. For example, a DIAC can be used to discover all Bluetooth devices within range that are dedicated to a particular piconet. According to the Bluetooth specification, DIACs are specially chosen to tolerate a higher bit error rate than a body of a message, such that they can be detected beyond a range at which a Bluetooth transmission would normally be corrupted. This is so that they can achieve their function of being detected by a receiver even before a clock synchronization is achieved between the transmitting and receiving devices.

[1028] Fig. 3A demonstrates a conventional transmission format, which is used by the invention except as discussed below. In Fig. 3A, 72 bits within section 310 of the transmission format are reserved for one or more of the access codes discussed above. The 54 bits in the section 320 are used as a header for identifying the type of device/content, etc., as is conventional, and the remaining 2745 bits in section 330 are used for the payload of the transmission.

[1029] According to one embodiment of the present invention, a device 110 that desires to transmit first attempts to communicate in the normal fashion; i.e., transmitter 210 sends out a burst having the above format. If receiver 220 of device 110 is able to hear a recipient device, but the other device does not respond (or if receiver 220 receives nothing in response), error-correcting coding mechanism 240 then tries re-coding the message into a low-rate packet or packets which are transmitted by transmitter 210 under a specially reserved DIAC. That is, the entire packet, including the original access code and header, are re-coded and prefixed with the reserved DIAC.

[1030] On the receiving side, when a device equipped with this invention hears one of the reserved DIACs, it begins decoding the remainder of the burst (note that, as discussed above, DIACs are more robust than a typical Bluetooth data packet, and may thus be received by the receiving device even at a distance where the first, initially-sent data packet is unrecoverable). The first subsequent part of the burst will be the original access code. The receiving device looks

[1031] Fig. 3B demonstrates a transmission format used to implement this embodiment of the invention. In Fig. 3B, access code 310, header portion 320 and payload portion 330 remain the same. However, DIAC 340 is now appended as a burst preamble that serves as a warning that the burst to follow is at a lower effective rate than normal Bluetooth bursts. The remainder of the burst after the DIAC can then be transmitted with the same modulation as usual, but with each bit time extended by a factor determined by the choice of DIAC. Thus, in Fig. 3B, although the length of the DIAC is 72 as is standard for a DIAC, the remaining portions are multiplied by the exemplary 2x extension factor. As mentioned above, this bit time extension allows for increased ECC, which in turn increases the signal-to-noise ratio of the signal and allows reception of the signal at a distance beyond the nominal maximum range of the transmitting device.

[1032] For example, a DIAC might be reserved to signify a 2x extension of the bit time, reducing the effective data rate to one half. Another DIAC might call for a 3x extension, or an extension of only 50% (1.5x). The receiver, based on the DIAC preamble, can then take advantage of the extended bit times to perform a more robust decode of the payload of the burst. Of course, as alluded to above, such a process requires additional time, increasing the time necessary to receive the payload portion 330 in proportion to the selected bit time extension. If the bit extension causes the packet to exceed the maximum length (in time) of the Bluetooth packet, it will be necessary to insert additional packets or change the packet type to use more slots. Nevertheless, despite the increased time required to decode the payload, the present invention is advantageous in that it provides a user with additional transmission range and time, thereby allowing the user the opportunity to, for example, end the transmission or move back to within a standard transmission range.

[1033] Since the modified DIAC is compliant with the Bluetooth specification, devices which are not equipped with the present invention will simply ignore the DIACs which are used, the same as any burst not addressed to it. Even if an unequipped device were to attempt to decode the entire burst, error checks will fail due to the extended bit times (which will appear to the receiver 220 as bit replications).

[1037] For example, as shown in Fig. 4, if a device 110 is communicating with device 120, at some point it may notice a drop in signal strength indicating that device 110 is moving out of range to a new location. As just discussed, if the device 110 is participating in an extended network that supports data forwarding, device 120 may begin searching for another device (e.g., device 410) that can forward data to device 110. However, as was also just discussed, by the time it finds one, direct communication may already have been lost, and/or the dropout may occur abruptly.

[1038] In these cases, device 120 may attempt to notify device 110 via a low rate burst according to the present invention, so that communication can be continued without interruption or resumed quickly. That is, devices 110 and 120 can continue to communicate via link 140, as discussed with connection to Figs. 1 and 2 above, until such time as device 120 locates device 310. At that point, messages between devices 110 and 120 may be forwarded using device 410, via links 420 and 430. In this way, a user may experience an easy, transparent and continuous hand-off. It should be noted here that the just-described hand-off process, as with various other processes of the present invention, could also be controlled by a user, either as a default or override process. For example, a user may wish to manually control hand-off when the automatic process is repeatedly bouncing the user to forwarding devices that are not appreciably different from one another in transmission quality.

[1039] The process just discussed is described in more detail, for a particular embodiment of the invention, with respect to the flowchart 500 shown in Fig. 5. In step 505 of the flowchart, device 110 sends a standard Bluetooth poll for subsequent data transmission(s) to device 120. In step 510, device 110 determines whether a response is received from device 120 with acceptable signal strength. If such a response is received, standard Bluetooth transmissions are continued in step 515. Otherwise, device 110 sends out in step 520 a special-purpose DIAC, as discussed above, to alert device 120 that subsequent data will receive a particular level of increased error-correcting coding.

[1040] If device 110 then receives a response in step 525, it may increase ECC in step 535 to maintain transmission, while simultaneously searching for a forwarding device (as discussed with respect to Fig. 4). If an unacceptable response is received in step 525, device 110 may nevertheless continue searching for a forwarding device in step 530 (and may propose gradually-increasing levels of increased ECC to device 120 in step 520 until an appropriate response is

received in step 525). Although not demonstrated in Fig. 5, it is possible that device 110 may either move back into standard transmission range with device 120 (in which case normal transmissions may resume), or may move completely out of range of device 120 via any available forwarding device (in which case transmissions must cease). Once an acceptable forwarding device 410 is found in step 540, device 110 can continue normal transmissions via that device. Of course, if no forwarding device is located, searching continues in step 545, until transmissions end after a predetermined time, or until device 110 moves back to within normal operating range of device 120.

[1041] In conclusion, the above description has provided various explanatory embodiments to explain a methodology for extending an effective transmission range of a wireless device. The methodology may be implemented in a number of settings; for example, at the outset of a connection between two devices if necessary to establish the connection, at an ending of a connection when the connection has actually been lost, or at a fading of the connection (as detected by a decrease in RSSI or increase in bit error rate) when the connection may be imminently lost. The methodology may also be implemented between different types of devices; e.g., between a class one and a mobile class two device or between two class two devices. Thus, by virtue of the present invention, transmissions can be made more reliable, and abrupt stoppages or interruptions of transmissions can be avoided.

[1042] While this invention has been described in various explanatory embodiments, other embodiments and variations can be effected by a person of ordinary skill in the art without departing from the scope of the invention. For example, the invention additionally contemplates applying different error correcting coding techniques instead of merely extending bits in the context of standard Bluetooth error correction.